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# The PSYCHOLOGICAL RECORD . . . .

MAY,  
Vol. IV

1941  
No. 17

LIGHT-AVERSION IN THE WHITE RAT

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THE PRINCIPIA PRESS, INC.  
BLOOMINGTON, INDIANA

Price of this number, 35 cents

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## LIGHT-AVERSION IN THE WHITE RAT

By FRED S. KELLER

A relation between the presence or absence of illumination and the amount of general activity of the white rat has been demonstrated by Slonaker (8), Richter (5), and others—most recently by Hunt and Schlosberg (2); and observations have also been made which indicate a depressive effect of light upon the specific activity of lever-pressing under hunger drive (6). In addition, the possibility of light-dark preference, prior to training, has long been recognized in studies of visual discrimination. For the most part, however, investigators have ignored the motivational problem lying behind the rat's nocturnality or stimulus-choice.

Only in the case of very young animals has this problem been approached: by Crozier and Pincus (1) and, especially, by Turner (9). Crozier and Pincus have reported a "seeking of the dark" in young hooded rats after the eyes were opened—a mode of response clearly distinguishable from the earlier tropistic orientations of 8- to 14-day-old animals. Turner, in his study of the first "eidoscopic," non-tropistic orientations of albinos, 14 to 19 days old, employed light as an "irritating" as well as a discriminative stimulus; and he remarks, in a footnote, that "the use of illumination as a motivating factor constitutes a contribution to methods of experimentation on young albino rats; varying its intensity allows some control over the degree of motivation."

The present exploratory study was undertaken with the two-fold purpose of determining (1) whether or not such a motive could be demonstrated as influential in the lever-pressing behavior of adult albino rats; and (2) whether or not the motive, if existent, was related to intensity of illumination.

The apparatus was a modified form of the device used by Skinner in his early studies of the lever-pressing response (6, pp. 48-51). The floor of the animal's compartment, in the present experiment, was approximately 5 cm. below the response-lever in its resting position, and was covered with a thin layer of sawdust. The detachable top of the compartment was removed during ob-

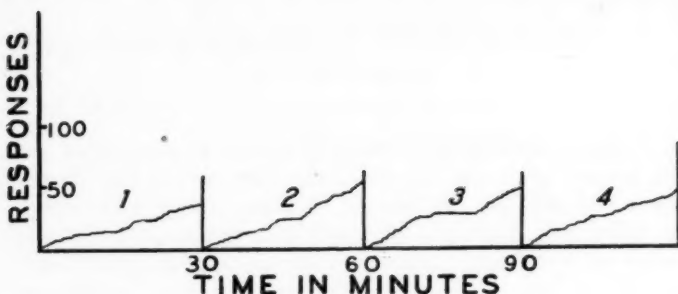


FIGURE 1

#### CONDITIONING OF THE LEVER-PRESSING RESPONSE IN FOUR RATS UNDER LIGHT-MOTIVATION

Each curve is cumulative and includes those responses which terminate the light and those which occur during each 1-minute reinforcement.

servation periods and replaced by a plate-glass cover. About 15 cm. above the approximate center of the glass cover, and 45 cm. from the compartment floor, was the bulb of a student lamp with reflector. This lamp was in circuit with a telegraph key which was on the experimenter's table about 20 ft. away from the apparatus and behind two partitions which projected into the experimental room. Beside the telegraph key was a small red signal-light, connected with the animal's response-lever through a mercury contact, which flashed on whenever the lever was depressed. An additional well-shielded dim light, at the experimenter's table, permitted sufficient illumination for record-taking without altering the illumination in the neighborhood of the response chamber. Also connected with the lever was an ink marker which moved upwards just perceptibly on the paper-covered surface of a slowly revolving drum whenever there was a lever depression. (This drum was situated just outside the apparatus and geared to an electric clock motor so as to revolve once in six hours.) The records obtained, tracings of which are reproduced in Figures 1 and 2, were stepwise upward and cumulative.

After several preliminary experiments with individual animals

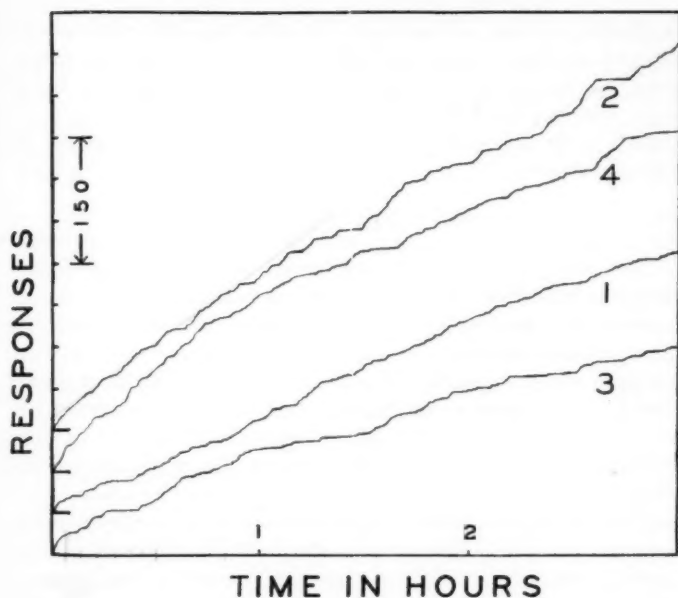


FIGURE 2

#### EXTINCTION OF THE LEVER-PRESSING RESPONSE IN FOUR RATS UNDER LIGHT-MOTIVATION

These are cumulative response-curves in which no response was reinforced with darkness.

under a variety of experimental conditions, the procedure outlined below was adopted with 4 male rats, approximately 100 days old and without any previous acquaintance with the apparatus. These animals had been housed for more than two weeks in almost totally darkened cages, except during periods (no more than one per day) of feeding, cage-cleaning, etc., which seldom lasted for more than half an hour.

Prior to all the experimental sessions described below small lumps of food (Purina Dog Chow, the regular diet) were strewn about the floor of the response chamber, and a glass drinking-tube was always placed within easy reach of the animal above the

horizontal cross-bar of the lever. In addition, a plentiful supply of food and water was at all times on hand in the animals' home-cage. The regular diet was occasionally supplemented, in the home-cage, with raw vegetables and table-scraps. All four animals appeared to be in excellent health during the 5-months' period of experimentation.

#### PART ONE

Lever-pressing was conditioned on the first day of the experiment, in the following manner. An animal was placed in the response chamber, under 101 foot-candles illumination, with the glass cover in position. Upon the first depression of the lever, the light was extinguished for a 1-minute period. At the termination of this interval it was again switched on, to be turned off again, when the rat next responded, for another minute of reinforcement. This was continued during a 30-minute experimental session. Thus, every 1-minute period of reinforcement with darkness was contingent upon the rat's depression of the lever in the presence of light. Responses to the lever in darkness were, of course, recorded, but did not alter the amount of reinforcement that the rat received on each occasion—that is, a response made during darkness did not extend the period of darkness for the animal.

It may be noted here that the subjects were given no preliminary period of acclimatization to the response chamber. Earlier tests with other animals suggested that such a period greatly *reduced* the speed with which conditioning took place. Indeed, more recent observations of 100-day-old animals indicate that conditioning may even take place in the absence of any previous gentling or acclimatization, with as few as two or three reinforcements.

The first day's record of each animal's lever-pressing, lasting 30 minutes, is shown in Figure 1. The striking similarity of these curves was unexpected and, it may be added, has not been quite so apparent in the records of another group of rats conditioned more recently in the same experimental situation. It seems likely that the first portion of each curve is mainly indicative of 'random' lever-pressing, whereas the second portion indicates that the response has been conditioned. This opinion derives support from

the temporal distribution of the animals' responses in darkness and under illumination. Responses during the first ten or fifteen minutes of the session followed the onset of light at very irregular intervals; towards the end of the session this variability was greatly decreased, one or more responses usually occurring within a few seconds after the light went on.

Even in the final portion of each curve, however, there are 'superfluous' responses—responses in excess of those required for the termination of the light; and this fact may be thought to weaken the argument that responding 'to get rid of' the light or 'to obtain' the darkness has really been conditioned. In advance of data to be presented later, it may be mentioned here that this superfluous pressing constitutes a special problem, but should not be taken as an invalidation of the efficacy of darkness as a mode of reinforcement.

Following the collection of the data represented in Figure 1, each of the four subjects was given a total of thirty 15-minute experimental sessions under the same conditions of illumination and reinforcement. These observations were made at irregular intervals over a 40-day period, and were about equally distributed with respect to morning, afternoon, and evening hours of experimentation. In several cases records were taken twice on a single day and, on a few occasions, three times; otherwise the tests were separated by at least 12 hours, and sometimes by as much as three or four days.

During the period of the first ten of these tests the home-cage conditions of illumination were similar to those described above, that is, the animals lived in almost complete darkness when not in the apparatus. During the period of the second ten tests, however, their living-cage was at all times under the illumination provided by a 50-watt light at about one meter's distance from the animals and placed so as to eliminate any deep shadows in the cage itself. Subsequently, five records were obtained under living conditions of darkness and, finally, five more records under living conditions of light.

In each of these thirty tests kymograph records were taken of the total number of responses made by the subject during the 15-minute period, and a supplementary record was kept by the ex-

perimeter of the number of responses occurring during each 1-minute reinforcement. In addition, for the last twenty tests with each animal, stop-watch measurements were made of the time elapsing between each light presentation and the first subsequent response to the lever.

The results of these tests are summarized in Tables I and II. Table I gives the average number of responses and, in parentheses, the range for each rat during the 15-minute test periods under each successive condition of living-cage illumination. Table II

TABLE I

Stage	Home-Cage Condition	Subjects			
		Rat 1	Rat 2	Rat 3	Rat 4
I (10 tests)	Darkness	22.3 ( 7-29)	20.9 ( 9-29)	27.8 (24-34)	36.9 (29-45)
II (10 tests)	Light	32.0 (22-53)	32.6 (18-48)	26.7 (21-36)	30.3 (24-43)
III ( 5 tests)	Darkness	30.4 (28-33)	37.0 (32-45)	43.4 (32-58)	54.2 (41-63)
IV ( 5 tests)	Light	36.8 (32-41)	35.3 (31-49)	34.3 (27-43)	58.5 (43-72)

Average number of lever-pressing (ranges in parentheses) made by four rats during thirty 15-minute tests under home-cage conditions of darkness and light, when each lever-pressing response in the presence of a 101 f.-c. light was reinforced with one minute of darkness.

TABLE II

Stage	Home-Cage Condition	Subjects			
		Rat 1	Rat 2	Rat 3	Rat 4
II (10 tests)	Light	7.8 (2.05)	15.6 ( 4.09)	8.0 (2.38)	5.2 (0.54)
III ( 5 tests)	Darkness	12.7 (7.04)	21.6 (13.38)	5.3 (0.54)	6.4 (4.02)
IV ( 5 tests)	Light	8.4 (2.25)	10.3 ( 2.60)	5.2 (1.20)	4.3 (0.60)

Average reaction-times to a 101 f.-c. light (A. D.'s in parentheses) for four rats during twenty 15-minute tests under home-cage conditions of darkness and light, when each lever-pressing response in the presence of light was reinforced with one minute of darkness.



gives the average 'reaction times,' in seconds, together with the average deviations (in parentheses), for each rat during the last three conditions only.

In Table I there is apparent a trend in the direction of increased responding from the beginning to the end of the test series. There is, however, no clear-cut effect of the conditions of home-cage illumination upon the response number; nor are there any very consistent individual differences, save in the case of rat 4 whose lever-pressing was more frequent than that of rats 1, 2 and 3 in most of the tests.

It may also be seen in this table that 'extra' responding continued throughout all of these tests and is not, therefore, characteristic merely of the initial 30-minute record shown in Figure 1. In all but five of a total of 120 cases this was true. Moreover, the number of responses made during a 15-minute session was, in more than half the total number of cases, at least double the amount required for the maximal number of reinforcements—namely, 14. Indeed, as many as 72 responses were made by rat 4 in a single session.

With respect to the 'reaction times' in Table II, there is some indication of the influence of home-cage conditions during the tests for which there are data. In three out of four cases the animals responded more slowly and with greater variability in Stage III (home-cage darkness) than in either of the other two stages; there are more consistent individual differences than appear in terms of response frequency; and, except in the case of rat 1, there is suggested a trend toward shorter reaction times in the second series (stage IV) under home-cage illumination.

On the day following the completion of these 15-minute sessions of regular reinforcement each animal was placed in the apparatus for a 3-hour period in which no responses to the lever were reinforced. Except for the uninterrupted presence of the light above the response chamber (and a certain resultant increase in the heat of the chamber), conditions were the same as those which prevailed during the earlier observations.

The cumulative extinction curves obtained are reproduced in Figure 2. These curves are somewhat similar to those obtained when hunger drive has been employed, especially those following

periodic reconditioning (6). The characteristic negative acceleration is present, along with those deviations introduced by short periods of eating, drinking, and other activity (or inactivity); and there is no indication of complete extinction at the end of the 3-hour period. The total number of responses for rats 1, 2, 3, and 4, respectively, was 313, 471, 249, and 414.

#### PART TWO

The final stage of this experiment was concerned with making a rough, preliminary measurement of the relation of lever-pressing to light intensity. For this purpose, lights of 5, 9, 31, 101, and 152 foot-candles were employed; and periodic, rather than regular reinforcement of the response was provided. That is, each 1-minute reinforcement was withheld until after a 15-second exposure of the animal to the light. It was thus possible to relate the number of responses *before* and *during* reinforcement to the degree of illumination.

Ten 15-minute tests were made at each level of light intensity. These tests took place, as before, at irregular intervals, and under conditions of home-cage darkness. Five tests were made at each level of a descending series of light intensities, and five were made at each level of an ascending series. The first and last five tests for each rat were therefore with the brightest light. Between the descending and ascending series were inserted five control tests in which no light at all was used.

In Table III are presented the data for each animal at each condition of illumination. Columns A, B, and C refer, respectively, to (a) average response-number before reinforcement, (b) average total response-number, and (c) average reaction time—that is, time between the onset of light and the *first* response to the lever. (Each average combines the results of ascending and descending series.) The same data are graphically represented in Figure 3, in which the curves A, B, and C have been plotted from the averaged data of the similarly designated columns of Table III. Also included in Table III are the results of the control tests, in which every condition of the experiment was carefully maintained except the actual appearance of light above the response chamber. Since the individual records of these control tests indicate no regularity of 'reaction times' or of the distribu-

TABLE III

Light Intensity (foot-candles)	Subjects											
	1			2			3			4		
	A	B	C	A	B	C	A	B	C	A	B	C
152	18.7	43.8	11.0	21.6	45.1	10.5	23.2	55.2	8.9	29.7	69.0	8.3
101	18.9	47.2	10.0	21.9	55.5	10.1	22.1	56.8	9.4	26.2	64.4	8.1
31	11.4	34.1	14.0	12.1	37.8	15.2	16.6	45.6	10.5	26.5	64.3	7.6
9	6.6	27.1	23.9	7.8	30.2	21.9	16.0	45.7	11.4	15.8	51.3	17.2
5	4.8	24.0	35.3	8.0	30.3	27.2	13.3	45.5	16.7	15.6	54.0	18.1
0	—	12.1	—	—	21.8	—	—	4.8	—	—	27.4	—

Average number of lever-pressings before reinforcement (column A); average number of lever-pressings before and during reinforcement (column B); and average reaction times to light (column C) for four rats at each of five light intensities. Reinforcement was periodic (see text) and home-cage conditions were of darkness. Results of control tests with no light stimulation are included in column B.

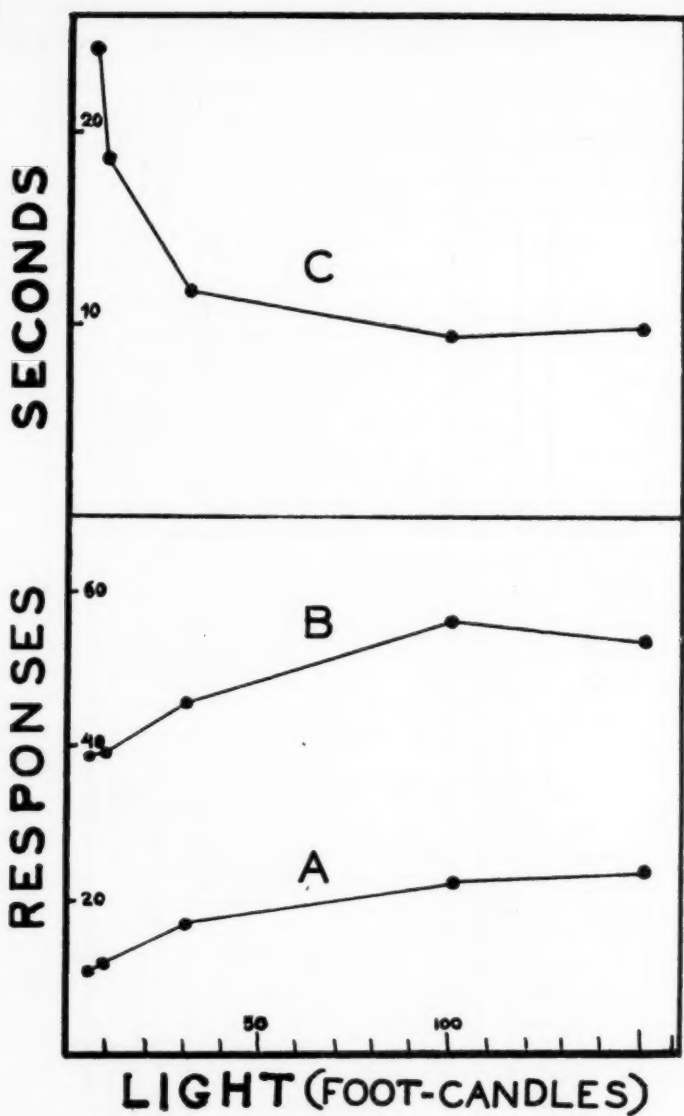


FIGURE 3  
PLOTTED DATA OF TABLE III

tion of responses during the 15-minute periods, only the total response averages are included in the table.

#### DISCUSSION AND CONCLUSIONS

The criterion of light-aversion in the present experiment is the 'strength' of the lever-pressing response. This strength of response, however, may be shown in a number of different ways.

When reinforcement is regular, as in Part One, reaction time provides one indication and frequency of response during reinforcement seems to provide another. Additional possible measures of strength are the *force* and *duration* of the individual responses made by animal. Under adequate conditions of observation, then, the strength of the reflex should show itself in some or all of the following: length of reaction time, number of extra depressions, force of the response, and duration of the response. When reinforcement is periodic, as in Part Two, still another measure appears, in number of responses *before* reinforcement.

In Part One there seems to be no striking parallel between reaction time and response frequency during reinforcement. Perhaps, however, the frequency of response during reinforcement is unreliable because it is obscured by the property of duration. Escape from light in this experiment was made contingent upon the *depression* of the lever and, obviously, one depression could not follow another until the lever had been released by the animal. Even in the early tests of the first series it was observed that the rats often held down the lever for a considerable time during the darkness reinforcement. Occasionally they held it down during the entire minute of reinforcement, thus affecting, in at least a slight degree, the length of the next reaction time. However, neither the duration of response nor the force of response were objectively recorded, so their effects cannot be properly evaluated at this time.

The significance of the extinction curves (Fig. 2) lies in their indication of a large 'reflex reserve' set up in each animal under light motivation and darkness reinforcement. The proportionality between the size of this reserve (i.e., the number of potential responses) and the strength of the lever-pressing reflex at any given stage of extinction may not, however, be adequately portrayed. There is, for example, the unknown effect of the change of tem-

perature in the response chamber during the extinction period, and there is the possible effect of a temporal discrimination to be considered. (The first sizable depression in the response rate of animals 1 and 3 appeared approximately 15 minutes after the beginning of extinction, which argues for a possible influence of the length of the preceding observation periods.) Moreover, extinction curves obtained more recently, following slightly different training conditions, are markedly different in slope from those presented here.

The degree of 'smoothness' in these extinction curves may also be related to the degree to which the duration of response interrupts the frequency. This need not seriously alter the over-all curve of extinction, but it does suggest that further restriction of experimental conditions may be of considerable analytic usefulness. Variations introduced by such interference of one dimension of the response with another would not, of course, be expected under hunger drive. Lever-pressing when food is the reinforcing stimulus is immediately succeeded by the other members of the reflex chain involved—that is, the lever is released and the animal lowers himself to the food-tray. In the present study, the operant conditioned is the *last* one in the chain and possesses unique properties. (For a discussion of the chain involved in this experimental situation, with hunger as motivation, see 6, pp. 52-55.)

The data of Part Two point to a relationship between the intensity of light and all three aspects of the behavior here considered—reaction times, response-frequency before reinforcement, and response-frequency during reinforcement. The grouped data are closely paralleled by the data for each individual. The exact nature of the functions is probably not revealed, since the unmeasured dimension of response-duration ('holding') may here, too, obscure the relation between light intensity and response-frequency, or reaction times, especially in the case of strong illumination; but it is clear that the technique of periodic reconditioning furnishes data (response-frequency before, or between, reinforcements) equivalent to that provided by reaction time and response-frequency during reinforcement.

With respect to the results of the five control tests, it may be

noted that there was no trend in any animal towards decreased responding throughout the series. It is possible, too, especially in the case of rats 2 and 4, that the number of responses in the control tests, in which no light was used, is in excess of the number of purely 'exploratory' responses that would have been made prior to conditioning. The possibility of excess lever-pressing of this sort is supported by certain later observations. At the conclusion of Part Two of the experiment, 24-hour records of response in darkness (with food and water supplied as usual) were obtained for each animal. During this period rats 1, 2, 3, and 4 made 495, 213, 592, and 921 responses respectively. These numbers are greater than would be expected on the basis of exploratory drive alone and give added significance to the control-test data.

The explanation of this type of excess responding should await a more direct attack upon the problem and a more adequate description of the operations of which the behavior may be a function. Nevertheless, the present observations are not without precedent in the experimental literature. Olson (4), for example, induced ear-scratching in rats by applying collodion to the ear-tips. After apparent recovery from inflammatory effects, there was 32 per cent more manifestation of the scratching activity in his two experimental animals than in two control animals that had not been irritated with the collodion.

It has been stated that the operant conditioned in this experiment possesses unique properties by virtue of its terminal position in the reflex chain. Some qualification of this statement may now be given, in the form of interpretative comment.

Skinner (6, pp. 12-19) has enumerated certain 'static laws' of the reflex. Among these he includes the following:

*"The Law of Latency.* An interval of time (called the latency) elapses between the beginning of the stimulus and the beginning of the response."

*"The Law of the Magnitude of the Response.* The magnitude of the response is a function of the intensity of the stimulus."

*"The Law of Temporal Summation.* Prolongation of a stimulus or repetitive presentation within certain limiting rates has the same effect as increasing the intensity."

*"The Law of After-Discharge.* The response may persist for

some time after the cessation of the stimulus."

According to Skinner these 'laws' apply only to *respondent* behavior—that is, behavior which is elicited by a stimulus. *Operant* or 'emitted' behavior, such as the lever-pressing response, "has no static laws comparable with those of a respondent since in the absence of a stimulus the conceptions of . . . latency, after-discharge, and the R/S ratio ['magnitude of response' above] are meaningless."

In the present study, an operant seems to take on the character of a respondent, in that the originally emitted behavior comes to be 'elicited' by the light-stimulation. We might, then, expect it to exhibit some of the static properties of the reflex or, better, the 'pseudo reflex' (cf. Skinner's discussion of the *discriminative stimulus*, 6, pp. 236-241). An examination of the data shows that such an expectation is at least partially warranted.

Most obvious of these properties, of course, is the *latency*, which has been called 'reaction time' in the present account; and a relation between this latency and the stimulus intensity is clearly apparent. In addition, although measurements are thus far lacking, many casual observations made during the present experiment suggest that the *force* of lever-pressing varies directly with both the duration and intensity of the light-stimulation—the laws of *temporal summation* and *magnitude of response*. Finally, the hypothesis may be advanced that both the 'holding' behavior and at least the first few of the 'extra' responses during reinforcement are phenomena of *after-discharge*, corresponding roughly to what Sherrington (7, pp. 25-35) described in the case of spinal reflexes elicited with faradic stimulation.<sup>1</sup>

Certain observations by Mowrer (3) are relevant in this context. Employing an escape-from-shock motive with rats and an operant similar to that of lever-pressing, he occasionally noted a 'freezing' or an immediate repetition of the response which terminated the shock, as well as responses during reinforcement which seemed to 'anticipate' the onset of the next shock. The observa-

<sup>1</sup> Dr. L. M. Hurvich has suggested to me that the extra responses during reinforcement may represent positive visual after-images. It is interesting, in this connection, to read Sherrington's remark that "the after-discharge of a reflex may be considered analogous to a *positive* after-image left by a visual stimulus."



tions of 'freezing' and repeated response under shock-aversion are obviously comparable to those of 'holding' and 'extra' responses under light-aversion and may also be treated in terms of after-discharge.

With respect to 'anticipatory' responding the case is not so clear. In the present experiment no very satisfactory measure was made of the temporal distribution of lever-pressing during darkness reinforcement. However, in more recent tests, including one in which a rat responded steadily throughout an 8-hour period of regular reinforcements, it appeared that the *first* part of the 1-minute darkness intervals is the part in which the extra responses occurred—at least after extensive conditioning had taken place. In other words, with light-aversion, responses during reinforcement do not seem to distribute themselves in such a fashion as to argue for the anticipatory behavior which Mowrer suggests.

It seems unlikely that after-discharge is descriptive of what appears to be superfluous lever-pressing throughout a long period of darkness after training. Such 'autonomous' behavior, if confirmed, would seem to require a different mechanism. In the absence of adequate data on this point, no speculation is warranted. After-discharge is here applied solely to those repeated (or prolonged) responses which occur during the first part of the 1-minute reinforcements in the training situation.

The present experiment points to the need for certain refinements in technique and it raises a number of problems the solution of which awaits these refinements. Yet the gross fact of light-aversion in the adult white rat appears to be established. This drive varies with the intensity of illumination employed; its strength may be measured by any one of several aspects of the response that is based upon it; and it promises to be a useful tool in the analysis of operant and respondent behavior.

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